CASE WESTERN RESERVE UNIVERSITY
CASE SCHOOL OF ENGINEERING



Creating Energy Alternatives
The Great Lakes Institute for Energy Innovation
Case Western Reserve University

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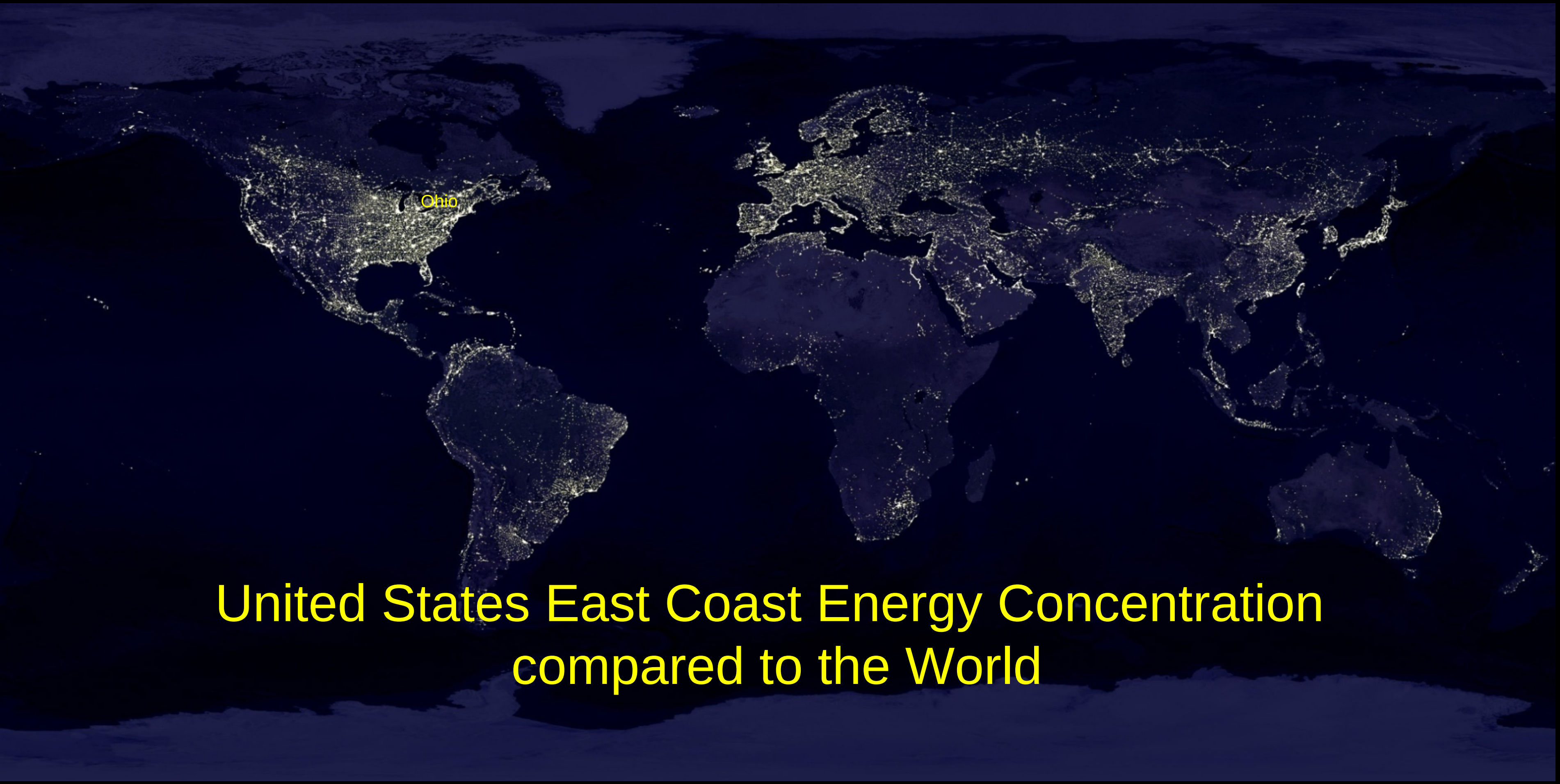
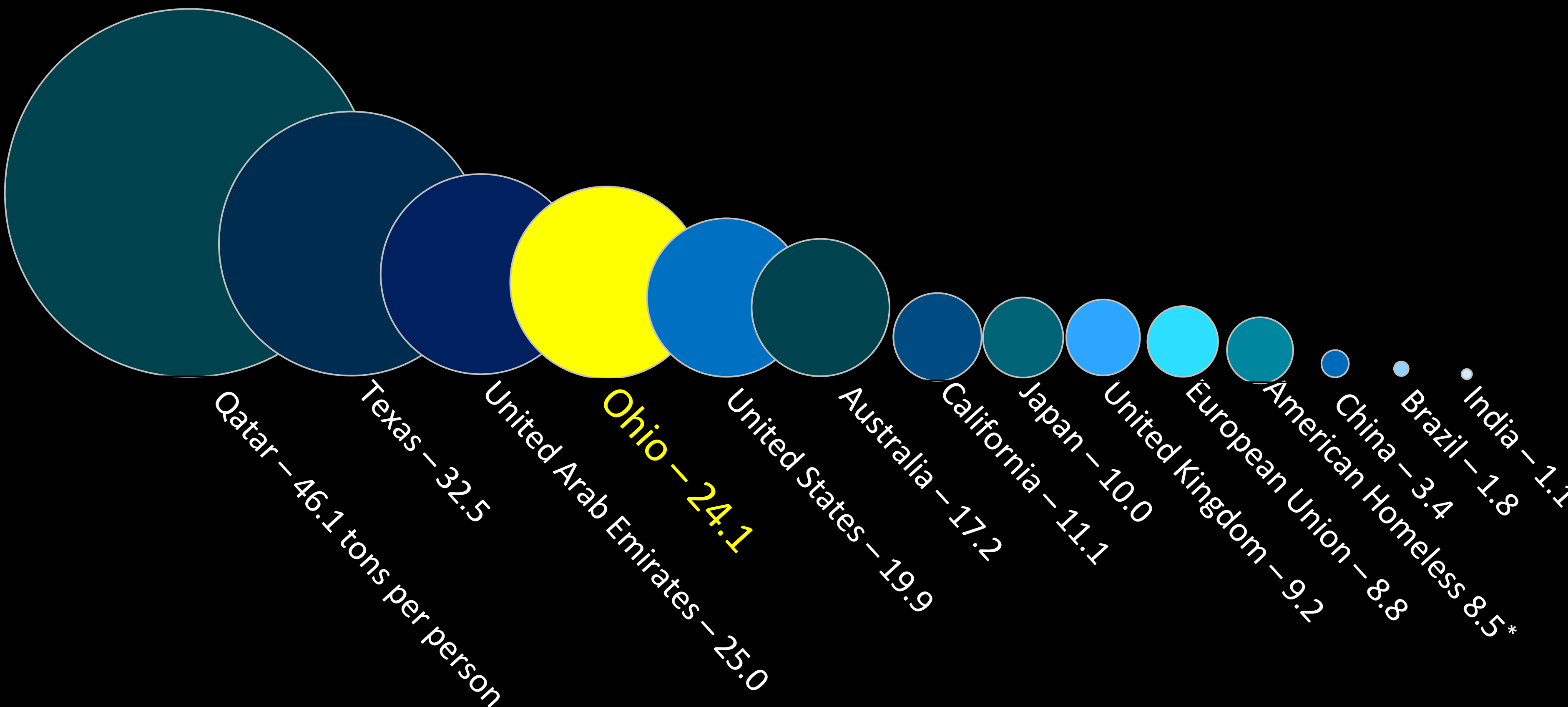
Geographic Location
Ohio
an ideal location for an Energy Institute

Lights! World Illumination Map



Ohio per capita Emissions are High
2003 (tons CO_2) Excludes Land Use Change



Great Lakes Geo-Economic Setting

Energy Concentration in Ohio

- Cleveland has a strategic position in wind and water in the United States.
- Rich in coal a common energy reserve to all Great Lakes States
- Significant potential for future coal-bed methane
- Energy consumption in Ohio's industrial sector ranks in top 10 in the Nation.
- Manufacturing history and infrastructure

Ohio's Research Infrastructure

- NASA Glenn: 1 of 10 NASA centers in the United States
- NASA Plumbrook: 6000 acres test facility
- Wright Patterson AFB
- Major research universities
- Centers of Excellence: fuel cell corridor, polymers, materials, solar
- NSF Science & Technology Centers
- Non-profit research: Battelle
- Commercial R&D: GE Nela Park, Lubrizol, Parker Hannifin, First Energy, Swagelok
- Supply Chain in renewable energy: 100s of companies, 75 in wind

Case Western Reserve University
A leader in IP and Research

University Positioning

182 years old

Diverse students from 50 states & 100 countries.

Student-faculty ratio 9:1

Fulbright, National Science Foundation, and Goldwater scholars

Endowment $1.8 billion

15 Nobel laureates alumni including first American to win the Nobel prize

Research & IP Positioning

Proven in leading large research centers

Top 50 large research university (only one in Ohio) *Academic Analytics*

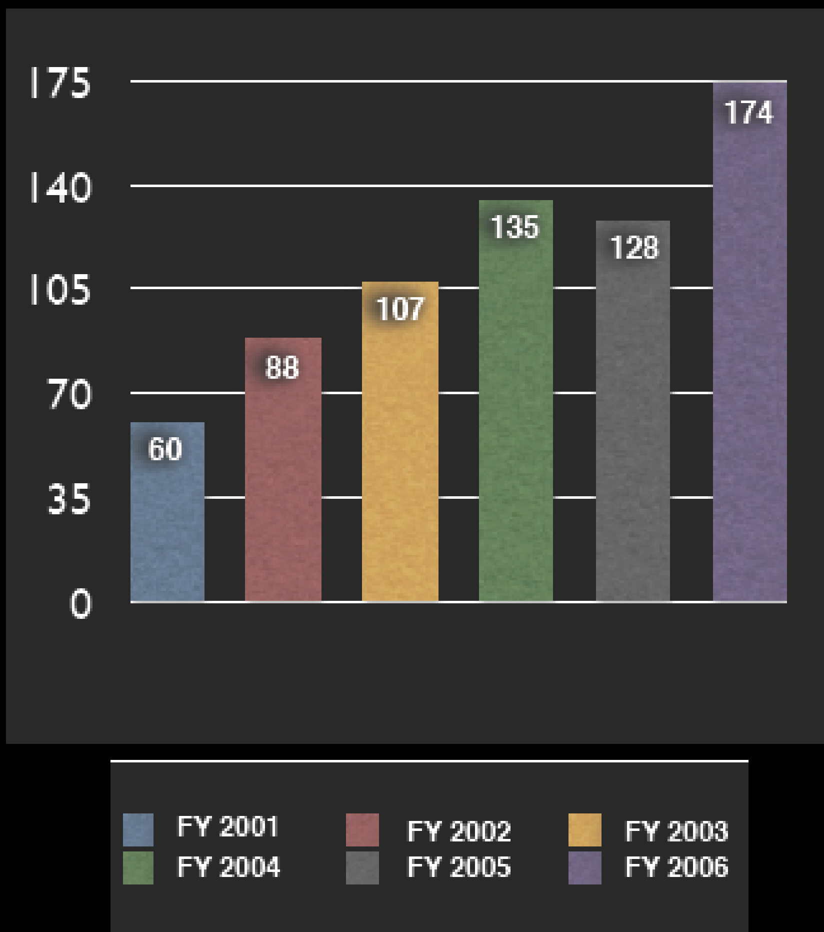
25th in Federal research dollars

Top ranking Schools and departments and house>100 Institutes & research centers

1 of 62 members AAU leading research universities in US/Canada

Commercialization
CWRU & Technology Transfer

Invention Disclosures



- **Over $300m in research dollars annually**
- **Technology Transfer one of the highest ranked in the U.S.**

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Creating Energy Alternatives

Mission

Enable the transition to advanced sustainable energy generation, storage, distribution and utilization through coordinated research, development, and education.

Research Thrusts

Renewable Power
- Wind
- Materials for next-generation solar

Storage
- Batteries
- Ultracapacitors
- Compressed air

Fuel Cells
- PEM, SOFC, DMFC

Management of Power Distribution
- Smart grids
- Power informatics

Energy Efficiency
- Clean combustion
- Synthetic fuels
- Industrial processing
- Energy efficient materials

Geologic Energy Systems
- CO2 sequestration
- Subsurface geochemical process modeling

Wind Power Research Challenges: Blade Design and Fabrication

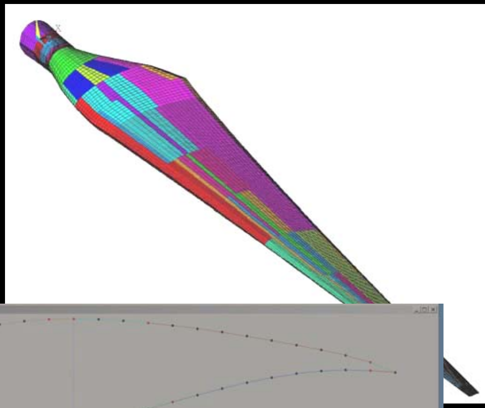
- Making longer lightweight blades is a primary focus for utility-size turbine manufacturers
- Blades ~ 10 percent of the overall capital expense
- Spending on blade innovations is small factor in energy production costs
- Benefits of better structural designs and improved fabricating techniques cascade throughout the turbine's cost structure.

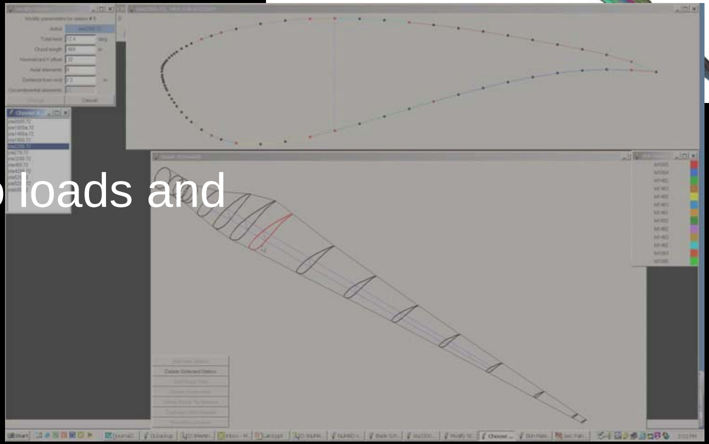
Vestas blade manufacture

Wind Power Research Challenges: Blade Design and Fabrication

Wind Turbine Blade Fabrication

- Materials – fiberglass, carbon fiber, carbon/glass hybrids, carbon fiber/epoxy
- Processing controls determine quality
- Increase processing speed without compromising mechanical properties
- Materials and substructure testing
- Finite Element Analysis of blade response to loads and failure modes
    - localized matrix yielding
    - fiber bridging





Wind Power Research Challenges: Blade Design and Fabrication

Wind Turbine Blade Design

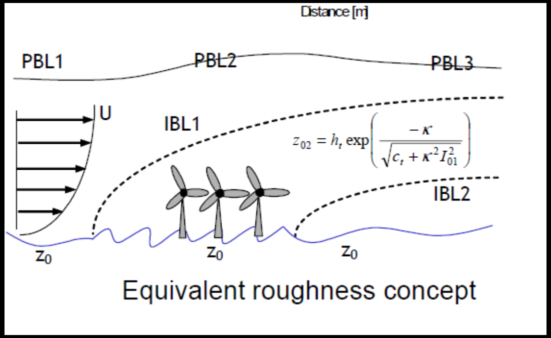
- Blade tip shape affects acoustic characteristics
  - tip velocity limited by imposed noise limits
  - Higher tip speed permits decrease in generator rotor diameter
- Aeroelastic modeling to develop designs that will lower twisting and loading
- Hierarchical models to predict materials failure modes

Wind Power Research Challenges: Blade Design and Fabrication

Wind Turbine Wake Models

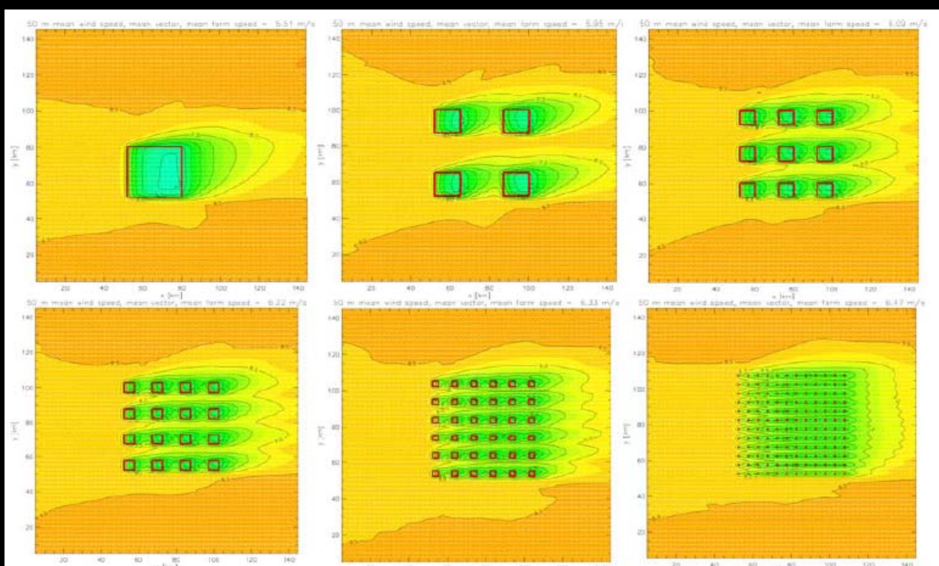
- Wake modeling is an important aspect of estimating the power loss in wind farms due to the wind speed reduction in wakes from up-wind wind turbines
- Simple analytical wake models used in conjunction with genetic algorithms to determine optimal turbine placement in wind farms

S. Frandsen,
IEA Workshop, Berlin, 2007



Wind Power Research Challenges: Wind Farm Design

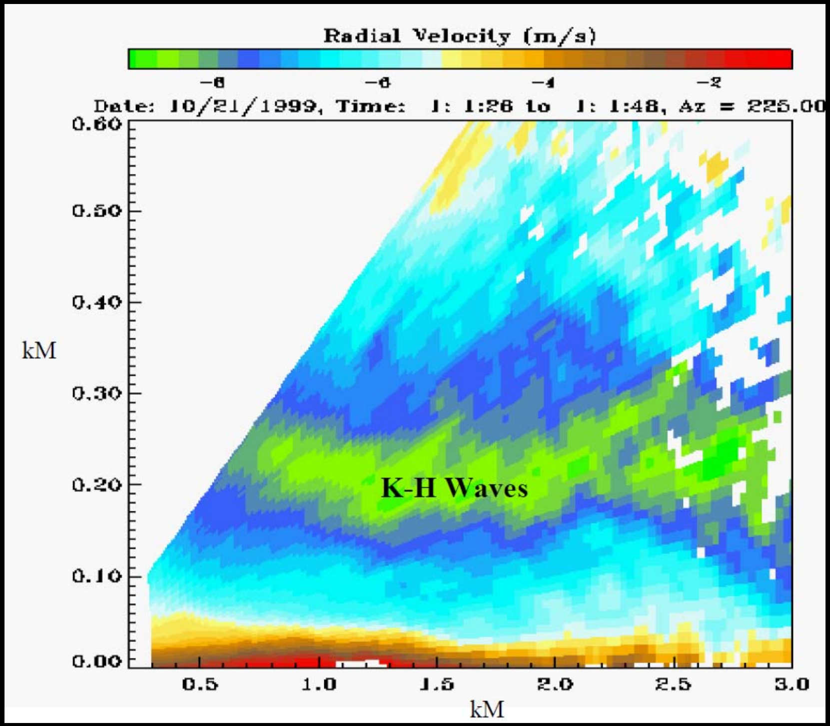
Wind Turbine Wake Models



S. Frandsen,
IEA Workshop, Berlin, 2007

- KAMM model by Frandsen
- To date, advanced and detailed wake models, even when including an explicit representation of turbulence and its impact on the wake expansion are unable produce convincing predictions

Wind Power Research Challenges: Design for extreme conditions



Kelvin-Helmholtz (K-H) instabilities form at the boundaries between these parallel layers

Thresher & Laxson, NREL/CP-500-39537, June 2006

Gust loads on entire turbine structures

- Low level nocturnal jet - cooling causes formation of parallel layers with different velocities
- K-H instabilities large-scale coherent vortices that can reach the ground - gust loads on turbine rotors.
- Prevalent in Great Plains States (Class 4)
- Effects of extreme coherent gusts on larger rotors on taller towers

Wind Power Research Challenges

Other Wind Power Research Areas

Gearboxes

- Improved gearbox materials
- Lubricants, sensors
- Gearless turbines, direct drives

Controls

- Advanced control systems for mechanical and electrical performance
- Active and reactive power control

Design of offshore structure

- Mitigating effects of loads from freshwater icing
- Assessing wave action effects on turbine poles
- Design of deep water turbines

Wind Power Research Challenges: Blade Design and Fabrication

Understanding Wind Turbine Icing

- Lower maintenance
- Decreased downtime
- Sensors for detection and de-icing control
- Decrease safety risks

Baring-Gould, 2005

www.tauernwind.com

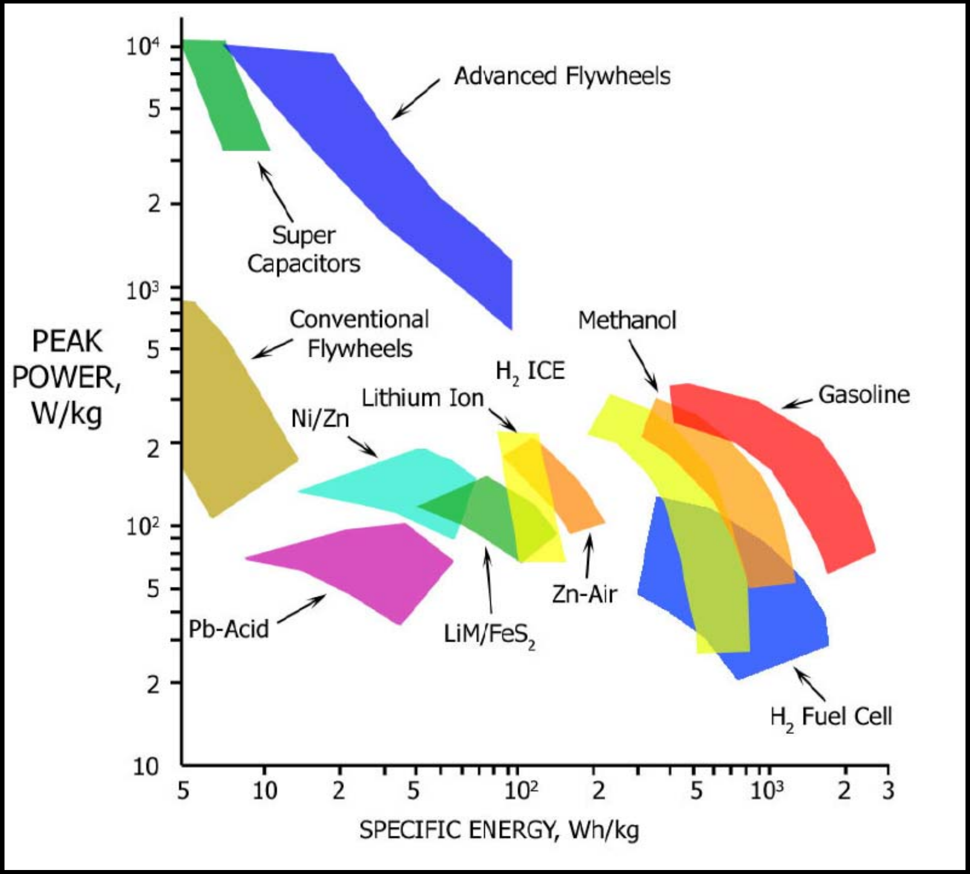
Hansen & Koppel, 2008

Energy Storage: A key to reliability

Modes of energy storage

- Potential energy (pumped hydro CAES)
- Kinetic (mechanical flywheels)
- Thermal (sensible and latent heat)
- Chemical (heats of reaction and combustion for biomass, fossil, hydrogen, etc.)
- Electrical (electrochemical, electrostatic, electromagnetic
- Batteries, flow batteries, super capacitors, SMES
- Power density versus energy density (weight and volume)

Energy Storage: A key to future energy reliability

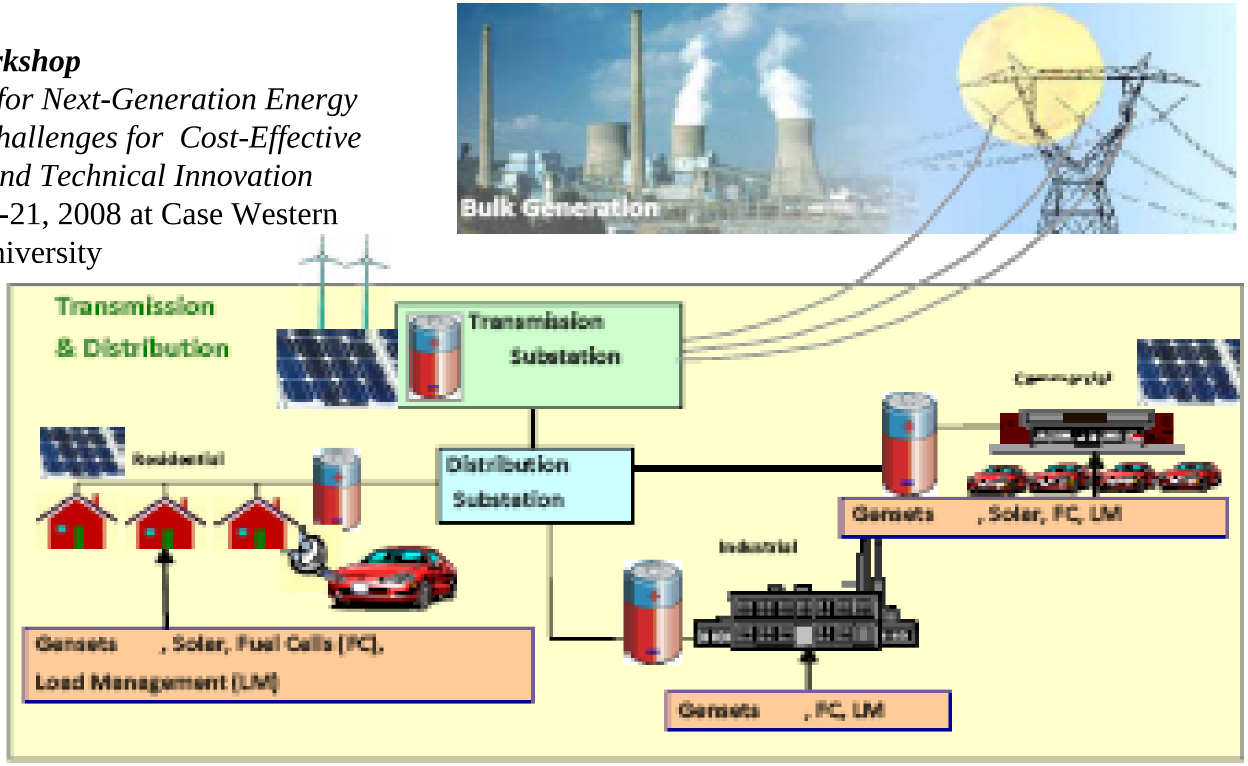


- “Changes the game” for wind/solar
- Distributed vs. utility scale
- Future static storage systems will be hierarchical
- Will a factor of 3 improvement be enough for transportation?
- Can impact fuel cells usage for transportation

Energy Storage Hierarchies

Energy storage is a key to our future

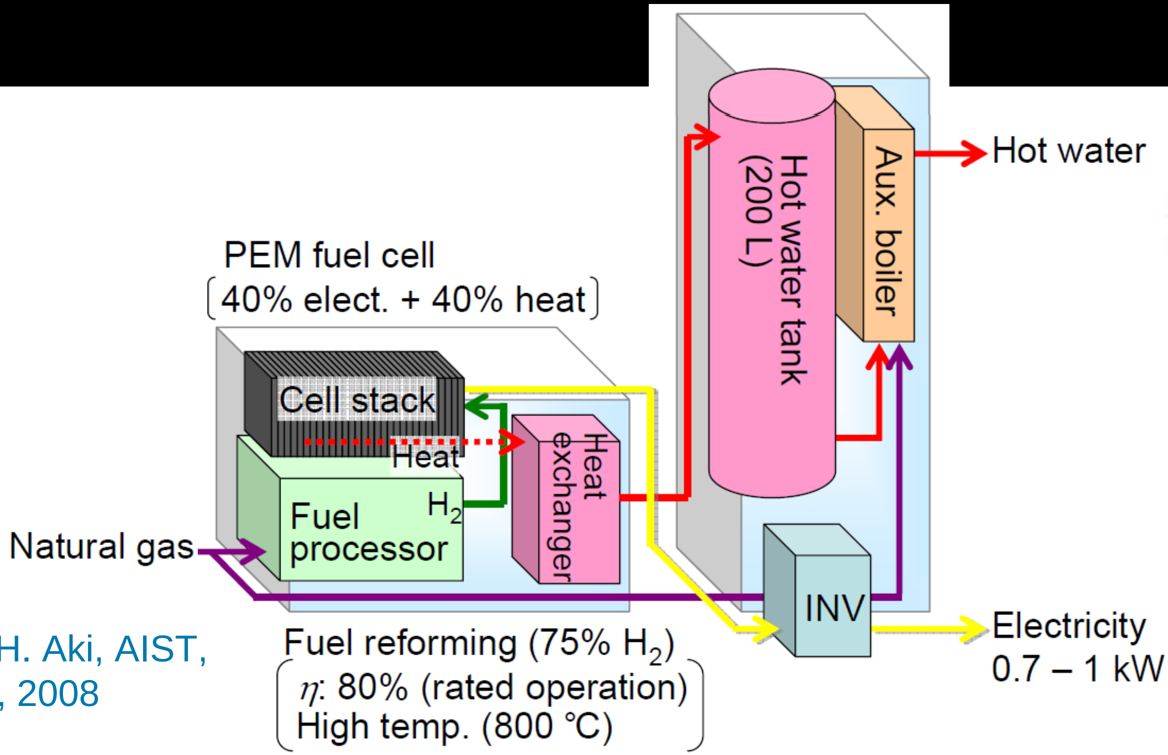
Source: Ali Nourai, American Electric Power
EPRI Workshop
Materials for Next-Generation Energy Storage: Challenges for Cost-Effective Scientific and Technical Innovation
October 20-21, 2008 at Case Western Reserve University



Fuel cells: Transportation or distributed cogeneration?

Fuel cells find early application as residential cogeneration systems in Japan

- Residential SOFC & PEM
- Distributed vs. utility scale
- Manufacturers: Ebara Ballard, Panasonic, Toyota, Toshiba, Sanyo



After, H. Aki, AIST, Japan, 2008

Smart Grid Networks/Power Informatics

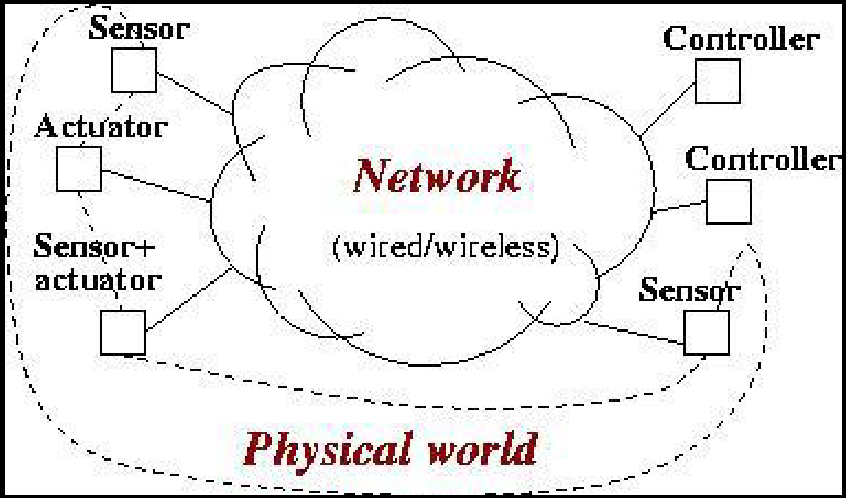
Smart Power Grid Networks

→ transform the electric power grid using advanced communications, control and software.

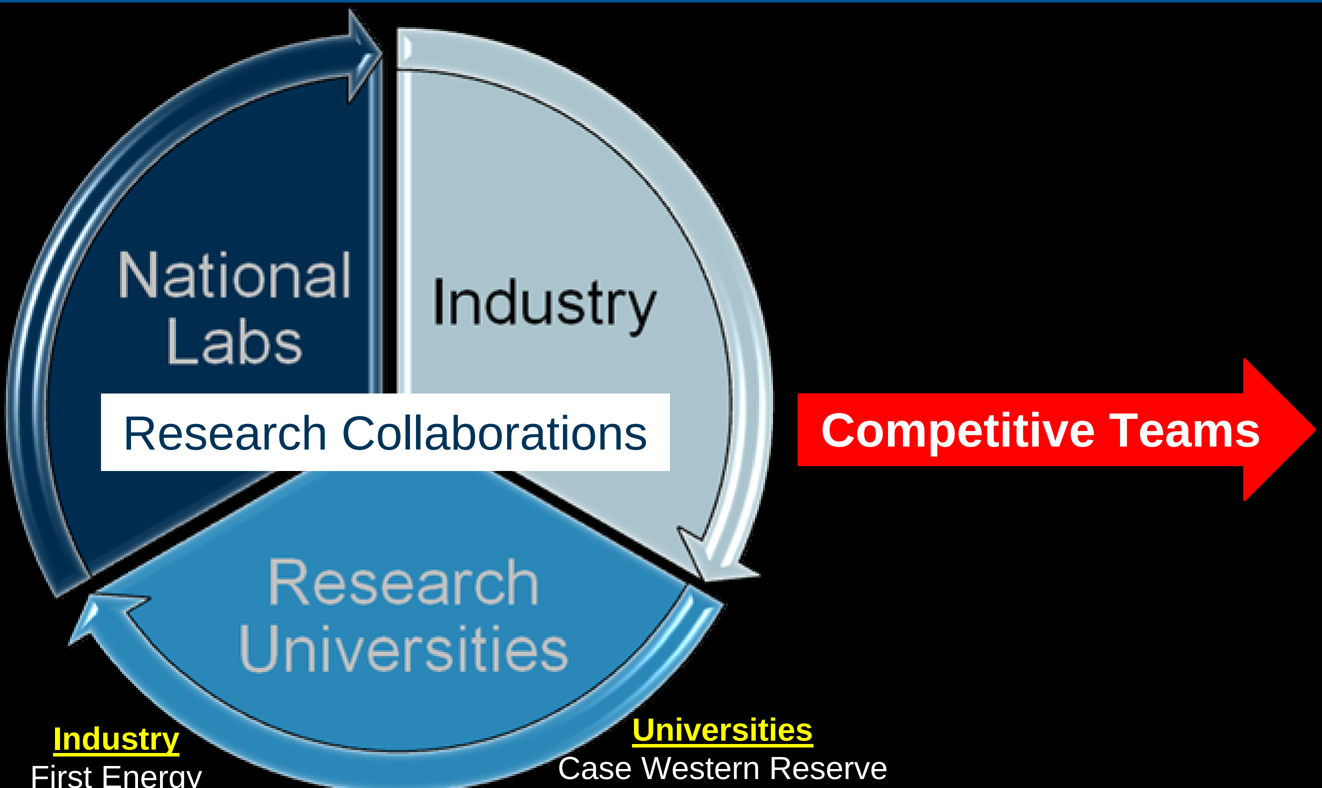
- Intelligent devices for generation, transmission, distribution and use
- Sense, respond, and share real-time information.
- Support collaborative management, planning, and operations
- Enable instantaneous communication, situational awareness, and control
- Increase productivity
- Enable plug-and-play asset integration
- Stabilize costs when supply is limited.

Distributed control of power transmission and distribution

- Smooth out demand curve, leads up to 30% savings in energy generation
- Distributed control, leads to substantial impact on renewable energy in the power grid



Building Research Capacity Through Strategic Collaborations



State & Federal Funding

Ohio 3rd Frontier
DOE
NSF
DARPA
DOD

Industry
First Energy
Lubrizol
Parker-Hannifin
Siemens
Swagelok

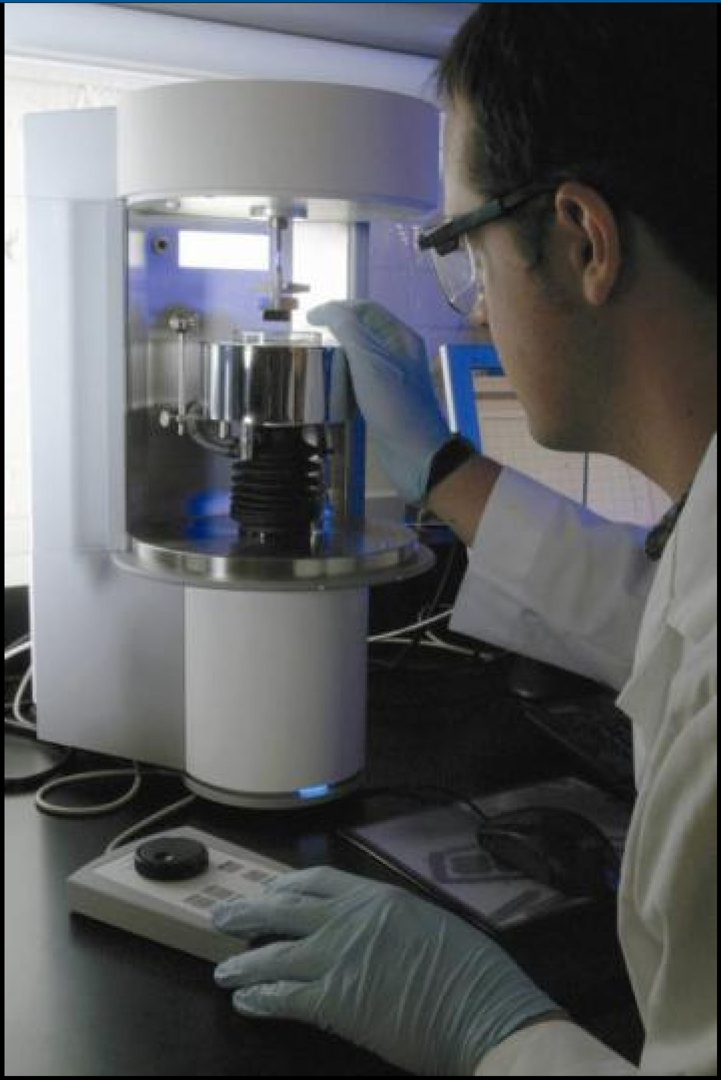
National Labs
Argonne
LANL
NASA GRC
Sandia

Universities
Case Western Reserve
Cleveland State U
Drexel University
MIT
Ohio State
University of Akron
University of Toledo
University of Michigan

Enhance Value Through Partnership with Industry

The Role of Today's University

- Research push: Game changing
- Research pull: Innovative Solutions
- Translational Research
- Commercialization: Spin-offs, licensing, new IP paradigm
- Economic development: An extension to education and research
- Test facilities, prototyping, standards



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The Great Lakes Institute for Energy Innovation

Through farsighted energy research and energy-use strategies; develop innovative energy-technology platforms that will provide low-cost, reliable and sustainable energy resources - and by implementing short-term solutions today, build and sustain tomorrow's industries.

Case Western Reserve University
Case School of Engineering



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